

UNITED STATES PATENT APPLICATION

**APPARATUS, METHODS, AND ARTICLES FOR A BLIND
GHOST CANCELLATION ON AN SD VIDEO**

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APPARATUS, METHODS, AND ARTICLES FOR A BLIND GHOST CANCELLATION ON AN SD VIDEO

Field of the Invention

5 The present invention relates to processing television signals, and, in particular, to ghost cancellation in standard definition (SD) video signals.

Background of the Invention

10 In a television (TV) receiver, a TV signal transmitted from a broadcasting station is converted into electric signals at a receiving antenna and is then converted into base band video signals by a tuner. A TV signal reaches an antenna via a plurality of paths by some shielding or reflecting in addition to its direct arrival.

15 The TV signal can get repeatedly reflected, due to possible geographic obstacles, such as buildings, and the like, and the reflected television signals can suffer a delay in time and a change in strength when compared with the a directly reached television signal. When reproducing the received television signals on a TV screen, these reflected TV signals may often produce ghost images.

20 There are a number of conventional ghost cancellation techniques based on using an internationally accepted Ghost Cancellation Reference (GCR) signal. Most of these techniques either use some form of an adaptive filter or an FFT (Fast Fourier Transform) based technique to identify the channel characteristics using the GCR and subsequently reduce the effect of a ghost image on a video signal. However, these techniques are computationally intensive and are complex to implement on a real-time basis. In addition, the use of the GCR signal is still not
25 very popular and hence is not very widely used.

Summary of the Invention

30 A ghost cancellation technique for multipath video signals received during transmission of a TV signal over a transmission channel. In one example embodiment, this is accomplished by computing edge parameters of synchronization signals received from each of the multipath video signals. A ghost associated with

each of the multipath video signals is then detected using the computed edge parameters. An input video signal is then selected from the detected ghost images and the remaining ghost images are then canceled using the selected input video signal and the computed edge parameters.

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Brief Description of the Drawings

FIG. 1 is a flowchart illustrating a ghost cancellation technique.

FIG. 2 illustrates a timing diagram of a typical video field transmitted via a transmission channel.

10 FIG. 3 illustrates a timing diagram of receiving multiple video signals due to multipath propagation/interference.

FIG. 4 is a flowchart illustrating an edge detection of a synchronization signal in a received multipath video signal.

FIG. 5 illustrates ghost image amplitudes detected over lines/fields.

15 FIG. 6 is a timing diagram illustrating a ghost image suppression achieved when using a horizontal synchronization (*Hsync*) signal to detect and cancel the ghost images in a multipath video signal.

FIG. 7 is a block diagram illustrating an example integrated circuit for implementing embodiments of the present invention.

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Detailed Description of the Invention

The present invention provides a computationally efficient technique that can be implemented on real-time basis to cancel ghost images in video signals received from multipaths that arise during transmission of a video signal through a transmission channel. In addition, the present invention does not use GCR signals to
25 detect and cancel ghost images, and therefore the technique is versatile and can be implemented to cancel ghost images even in systems that does not use GCR signals. In one example embodiment, the ghost images are cancelled using the detected edge parameters of synchronization signals in the received multipath video signals.

In the following detailed description of the embodiments of the invention, reference is made to the accompanying drawings that form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable
5 those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that changes may be made without departing from the scope of the present invention. The following detailed description is, therefore not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims.

10 The terms "ghost image detection circuit" and the "edge detection circuit" are used interchangeably throughout the document.

FIG. 1 is a flowchart illustrating an example embodiment of a method 100 of a ghost cancellation technique according to the present subject matter. At 110, the method 100 in this example embodiment receives multipath video signals via a
15 transmission channel. The video signals are received on a field-by-field basis.

Referring now to FIG. 2, there is illustrated a timing diagram 200 showing an example video data in each video field of a video signal transmitted via the transmission channel. As shown in FIG. 2, each video field includes plurality of video lines (such as the video line 210 shown in FIG. 2), a horizontal
20 synchronization (*Hsync*) signal 220 at the end of each video line 210, and a vertical synchronization (*Vsync*) signal including serration pulses 230 in the vertical blanking interval (VBI) portion of the video field at the end of the plurality of video lines and before the start of a new video field. Generally, each video line lasts for about 64 microseconds. There are typically about 262 (312) video lines including
25 video data in each video field in an NTSC (PAL) video standard. The time duration of a *Hsync* signal is about 4.7 microseconds. The time duration of a *Vsync* signal is about 192 microseconds (about 3 video lines). Also shown in FIG. 2 are the edges 240 of *Hsync* signals 220 and edges 250 of the *Vsync* signals 230 that are used in detecting and canceling the ghost images.

Referring now to FIG. 3, the timing diagram 300 illustrates a typical scenario of multipath propagation/interference caused by two video signals, one being a directly received video signal and the other being a reflected signal, 310 and 320, respectively, received via a transmission channel. As shown in FIG. 3 the reflected video signal 320 received via the transmission channel has lower amplitude than the directly received video signal 310. As shown in FIG. 3, the reflected signal 320 can have a time delay 't' with respect to the directly received video signal 310. It can be envisioned that any number of such multipath video signals can be received via the transmission channel due to a multipath interference. Further, FIG. 3 shows receiving synchronization signals 330 and 340 associated with the directly received and reflected video signals, 310 and 320, respectively.

At 120, edge parameters of each synchronizing signal are computed. The computed edge parameters can include a slope, amplitude, a time of occurrence, and so on. The computation of the edge parameters, such as slope of an edge of a synchronizing signal helps characterize whether an edge is a rising edge or a falling edge. At 130, the synchronization signal associated with each video signal (received from both direct and reflected signals) is detected using the computed edge parameters.

FIG. 4 is a flowchart illustrating an example embodiment of a method 400 of computing edge parameters and detecting associated synchronization signals according to the present subject matter. At 410, the method 400 in this example embodiment detects a current edge of a synchronization signal in the multipath video signals. In some embodiments, the detected current edge can be of a *Hsync* signal in a current video line and/or a *Vsync* signal in a current video field.

At 420, the detected current edge is compared with the previously detected edges stored in a table to see if the current edge is of an opposite kind and substantially equal in amplitude to one of the already detected edges in the table. For example, if the current edge is a rising edge then the previously detected and stored edges are checked to see if there is any falling edge having substantially equal amplitude in the table and vice versa. If the current edge is not of an opposite

kind to one of the previously stored edges in the table, then the current edge is included, i.e., stored, in the table at 425 and then the method 400 goes back to detecting a next edge of a synchronizing signal in the multipath video signal at 410. If the current edge is of an opposite kind to the one of the previously detected and
5 stored edges, then the previously detected and stored edge is selected and a current synchronizing signal is formed using the detected current edge and the selected previously detected edge at 430.

At 440, time duration between the current edge and the selected previously detected edge is computed. In some embodiments, if an edge-to-edge duration is
10 equal to *Hsync* width, i.e., equal to about 4.7 microseconds, then such edge pair is classified as a synchronizing signal. At 450, edge parameters, such as amplitude and a time of occurrence of the formed current synchronizing signal is computed. At 460, the selected previously detected edge is removed from the table.

At 470, the amplitude of the current synchronizing signal is compared to a
15 threshold value. If the amplitude of the current synchronizing signal is equal to or greater than the threshold value, the method 400 goes to act 410 to detect a next edge and a next synchronizing signal at 470. If the amplitude of the current synchronizing signal is less than the threshold value, the method 400 stops at 480.

At 140, an input video signal is selected based on the detected synchronizing
20 signals and the computed edge parameters. In some embodiments, the amplitudes of formed synchronizing signals are checked. A synchronizing signal having highest amplitude is chosen based on the outcome of checking. The video signal associated with the chosen synchronizing signal is selected as the input video signal.

At 150, ghost images from the input video signal are canceled. In some
25 embodiments, the amplitudes of the formed synchronizing signals are normalized to the amplitude of the synchronizing signal of the input video signal. The input video signal is then delayed by the time of occurrence of a substantially subsequent synchronizing signal. Remaining video signals are then canceled by multiplying the delayed input video signal with the normalized amplitude of the subsequent
30 synchronizing signal to cancel the ghost images from the input video signal.

In some embodiments, ghost images in the input video signal are canceled on a line-by line basis. In these embodiments, edge parameters, such as the slope, the amplitude, and the time of occurrence of the current edge in the current video line are computed. The slope of the current edge is then compared to slopes of the previously detected edges in the current video line stored in a table. A current *Hsync* signal is then formed by using the current edge along with the one of the previously detected edges, when the slope of the current edge is opposite the slope of the one of the previously detected edges stored in the table and a time duration between the current edge and the one of the previously detected edges is substantially equal to the *Hsync* width. Further, the amplitude of the current edge is computed. Furthermore, the one of the previously detected edges is removed from the table.

Also in these embodiments, the amplitude of the current horizontal signal is compared to a threshold value. The above-described acts are then repeated to form a next *Hsync* signal when the amplitude of the current *Hsync* signal is greater than or equal to the threshold value.

Further in these embodiments, amplitudes of the formed *Hsync* signals are checked. A formed *Hsync* signal having highest amplitude is then chosen based on the checking. The video signal associated with the chosen *Hsync* signal is then selected as the input video signal. The amplitudes of the formed *Hsync* signals are then normalized to the amplitude of the *Hsync* signal associated with the chosen input video signal. The input video signal is then delayed by a time of occurrence of a subsequent *Hsync* signal. The remaining video signals are then canceled by multiplying the delayed input video signal with the normalized amplitudes of remaining *Hsync* signals and subtracting them from the ghosted input video signal.

Referring now to FIG. 5, 500 illustrates ghost amplitudes that have been detected based on a line-by-line approach described above. The y-axis shows the amplitude of the ghost signal and the x-axis shows the delayed locations of the ghost signals in terms of pixels. It can be seen that the amplitude of the ghost images are reduced gradually over a few hundred video lines. FIG. 6 illustrates an example of a ghost image cancellation achieved using the line-by-line approach described above.

In some embodiments, ghost images are canceled on a field-by-field basis using edge parameters of start of a *Vsync* signal in each video field. In general, the serration pulses in the *Vsync* signal gives a sequence of edges, such as fall, rise, and fall with a defined duration between them. In these embodiments, a current edge of a vertical *Vsync* signal in the VBI in a current video field is detected. Edge parameters, such as a slope, amplitude, and a time of occurrence of the detected current edge are then computed. The computed slope of the current edge is then compared to slopes of previously detected edges stored in a table to see if there are any two edges having any of the slopes of the previously detected edges are of an opposite kind and any of the slopes of the previously detected edges are of a same kind. If two of the previously detected edges have a slope that is of an opposite kind and same kind to the slope of the detected current edge, then these three edges are selected. A current *Vsync* signal is then formed using the detected current edge and the selected previously detected edges. Also, time duration between the current edge and the selected previously detected edges is computed. Further, amplitude of the current edge is computed. Furthermore, the selected previously detected edges are removed from the table. If two of the previously detected edges do not have a slope that is of the opposite and same kind to the slope of the detected current edge, then the detected current edge is stored in the table along with the previously detected edges. The above-described process is then repeated to detect a next edge to form a next *Vsync* signal.

Also in these embodiments, the amplitude of the current vertical signal is compared to a threshold value. The above-described process is then repeated to form a next *Vsync* signal when the amplitude of the current *Vsync* signal is greater than or equal to the threshold value.

Further in these embodiments, the amplitudes of the previous and current *Vsync* signals are checked and a *Vsync* signal having highest amplitude is chosen based on the outcome of the checking. A video signal associated with the chosen *Vsync* signal is then selected as the input video signal. The amplitudes of the previous and current *Vsync* signals are normalized to the amplitude of the *Vsync*

signal associated with input video signal. The input video signal is then delayed by a time of occurrence of the *Vsync* signal having lower amplitude. Further, the video signal associated with the lower amplitude is then canceled by multiplying the delayed input video signal with the normalized amplitude of the *Vsync* signal having the lower amplitude and subtracting the lower amplitude signal from the input video signal (ghosted input video signal).

Referring now to FIG. 5, 500 can also be used to illustrate an example of ghost image amplitudes detected using the above-described field-by-field approach. The y-axis shows the amplitude of the ghost signal and the x-axis shows the delayed locations of the ghost signals in terms of lines. It can be seen that the amplitude of the ghost images are gradually reduced over a few fields. It can also be seen that the time required to reduce the ghost image amplitudes using the field-by-field approach can be longer than the time required to reduce the ghost image amplitudes using the line-by-line cancellation technique shown in FIG. 5. The reason being that the field-by-field approach reduces the amplitude of the ghost images on a video field-by-video field basis, where as, the line-by-line approach reduces the amplitude of the ghost images every video line and therefore requires lesser time to reduce the ghost image amplitudes. The advantage of the field-by-field approach is that the *Vsync* signals appear only once in the VBI portion of each video field, whereas the *Hsync* signals appear at the end of each video line and there is a good possibility that during an edge detection that a video signal having a similar edge can be detected as the edge of a *Hsync* signal. Therefore, the field-by-field approach of detecting a *Vsync* signal in the VBI portion of a video signal offers a more robust detection technique to cancel ghost images. Further, range of ghosts that can be reduced on a line-by-line approach is limited to around 12 microseconds, but with a field-by-field approach a much higher range can be achieved.

Although the flowcharts 100 and 400 include acts that are arranged serially in the exemplary embodiments, other embodiments of the subject matter may execute two or more acts in parallel, using multiple processors or a single processor organized as two or more virtual machines or sub-processors. Moreover, still other

embodiments may implement the acts as two or more specific interconnected hardware modules with related control and data signals communicated between and through the modules, or as portions of an application-specific integrated circuit. Thus, the exemplary process flow diagrams are applicable to software, firmware,
5 and/or hardware implementations.

FIG. 7 is a block diagram illustrating an example integrated circuit 700 including embodiments of the invention. The integrated circuit 700 shown in FIG. 7 illustrates an input module 710, an adaptive filter circuit 720, and a ghost image detection circuit 730 including a plurality of tapped delay lines 725. As shown in
10 FIG. 7, the input module 710 includes a delay equalizer 702, an input filter 704, and a MUX 706. Also as shown in FIG. 7, the ghost image detection circuit 730 includes a processor 732, a comparator 734, and memory 736. The integrated circuit 700 can be incorporated into an application specific integrated circuit (ASIC), a digital signal processor (DSP), and other such devices.

15 The ghost detection and cancellation algorithm processes synchronization signals, such as *Hsync* signal and the serration pulses in the *Vsync* signal. To improve noise immunity, the input filter 704 is switched into the input path during ghost detection. In order to equalize the data path delay, the delay equalizer 702 is added in regions of ghost cancellation. The MUX 706 switches between the delay
20 equalizer 702 and the input filter 704 during ghost cancellation and edge detection phases.

In operation, the input module 710 receives multipath video signals that arise during transmission of a television signal over a transmission channel. Each of the received video signals includes a synchronization signal. The processor 732, during
25 a ghost detection period, receives each video signal from the input module 710 and detects edges associated with the synchronization signals. The processor 732 then computes edge parameters of the detected edges and stores them in memory 736.

The processor 732 detects synchronization signals associated with each received video signal based on the computed edge parameters. In some
30 embodiments, the processor 732 selects a video signal as an input video signal from

the multipath video signals based on the detected synchronization signals and the computed edge parameters.

5 The processor 732 generates tap coefficients based on the detected synchronization signals. In some embodiments, the processor 732 generates tap coefficients using the input video signal, the detected synchronization signals, and the edge parameters. The adaptive filter circuit 720 receives the tap coefficients from the ghost image detection circuit 730 and controls the plurality of tapped delay lines 725 to cancel the ghost images.

10 In some embodiments, the processor 732 detects a current edge of a synchronization signal in the input video signal. The comparator 734 compares the detected current edge to previously detected edges stored in a table. The processor 732 then forms a current synchronization signal by using the current edge and the one of the previously detected edges in the table when the current edge is of an opposite kind to one of the previously detected edges in the table. The processor 732
15 then computes amplitude and a time of occurrence of the current synchronization signal using the edge parameters. The processor 732 then removes the used one of the previously detected edges from the table.

In these embodiments, the processor 732 normalizes the amplitudes of detected synchronization signals to the input video signal. The processor 732 then
20 computes a filter tap coefficient by using amplitude of a detected ghost *Hsync*. The adaptive filter circuit 720 then delays the input video signal and cancels remaining video signals based on the computed filter tap coefficient.

Also in these embodiments, the comparator 734 compares amplitude of the formed current synchronization signal to a threshold value. The processor 732 then
25 cancels a next ghost image if the amplitude of the next detected synchronization signal is greater than or equal to the threshold value.

In some embodiments, the input module 710 receives multipath line-by-line video signals. Each of these received video lines includes a *Hsync* signal. In these embodiments, the adaptive filter circuit 720 receives each video line from the input
30 module 710. The processor 732 receives each video line from the input module 710

and computes edge parameters in each video line. The processor 732 then detects each *Hsync* signal based on the edge parameters. The processor 732 then generates tap coefficients based on the detected video edges/syncs. The adaptive filter circuit 720 receives the tap coefficients from the ghost image detection circuit 730 and
5 controls the plurality of tapped delay lines 725 to cancel ghost lines.

In some embodiments, the processor 732 detects a current edge in the *Hsync* signal of a current video line in the video signal. The processor 732 then computes a slope, amplitude, and a time of occurrence of the current edge.

Also in these embodiments, the comparator 734 compares the slope of the
10 current edge to slopes of previously detected edges in the current video line stored in a table. The processor 732 then forms a current *Hsync* signal by using the current edge along with the one of the previously detected edges and computes an amplitude of the current edge and removes the one of the previously detected edges from the table if the slope of the current edge is opposite the slope of the one of the
15 previously detected edges stored in the table and a time duration between the current edge and the one of the previously detected edges is substantially equal to an *Hsync* width. In these embodiments, the processor 732 stores the current edge along with the previously detected edges in the table if the slope of the current edge is not opposite to the slope of the one of the previously detected edges in the table.

20 In other embodiments, the input module 710 receives field-by-field video signals. Each field includes a VBI. Each VBI includes serration pulses in a *Vsync* signal. In these embodiments, the processor 732 detects the *Vsync* signal in a current video field based on edge parameters of the serration pulses in the *Vsync* signal. The processor 732 then cancels a ghost image in a next video field by using the
25 computed edge parameters and the detected *Vsync* signal. The process of canceling the ghost image using the detected *Vsync* signal is explained in more detail with reference to FIGS. 4 and 5.

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Conclusion

The above-described invention provides an improved solution to cancel ghost images in multipath video signals. In addition, the above-described invention can be used in real-time and in systems where GCR signals are not available. This is
5 achieved by using edge parameters of synchronizations signals in the received multipath video signals.

The various embodiments of the ghost cancellation techniques described herein are applicable generally to any television signal processing, and the embodiments described herein are in no way meant to limit the applicability of the
10 invention. In addition, the techniques of the various example embodiments are useful to the design of any hardware implementations of software, firmware, and algorithms. The above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those skilled in the art. The scope of the invention should therefore be determined by the appended claims, along with the
15 full scope of equivalents to which such claims are entitled.